WHAT IS CLAIMED IS:

1.   A robot control apparatus having a position and speed control system for each axis of a robot in order to control a servo motor for driving the axis, comprising:

an angle measuring device for measuring a joint angle in relation to a joint coordinate system of the servo motor;

a motion torque calculating section for calculating a motion torque command which is required for a motion of the servo motor based on a joint command;

a disturbance torque estimating section for calculating a disturbance torque from a position and speed torque command calculated by the position and speed control system and the motion torque command;

a minute displacement relationship calculating section for calculating a minute displacement relationship between a task coordinate system of the robot and a joint coordinate system of the servo motor based on the joint angle;

an external force calculating section for carrying out a conversion to an external force on the task coordinate system by using the disturbance torque and the minute displacement relationship;

a force control section for calculating a position correction amount on the task coordinate system of the robot based on the external force; and

a joint angle correction amount calculating section for carrying out a conversion to a joint angle correction amount on the joint coordinate system by using the position correction amount and the minute displacement relationship.

2.   The robot control apparatus according to claim 1, wherein the motion torque calculating section includes:

a gravity torque calculating section for calculating a gravity torque of a joint section of the robot;

an acceleration torque calculating section for calculating an acceleration torque of the servo motor;

a speed torque calculating section for calculating a speed
torque for maintaining a speed of the servo motor; and

a motion torque adding section for adding the gravity
torque, the acceleration torque and the speed torque, thereby
5   calculating a motion torque.

3.   The robot control apparatus according to claim 1,
wherein the motion torque calculating section includes:

a second position and speed control system which is
10   different from the position and speed control system; and

a mechanical system imitating section imitating a robot
mechanism section.

4.   The robot control apparatus according to any of claims
15   1 to 3, wherein the force control section includes:

an impedance control section for calculating a position
correction amount on a task coordinate system of the robot
based on the external force; and

a correction amount selecting section for causing the
20   position correction amount to be valid or invalid.

5.   The robot control apparatus according to any of claims
1 to 3, wherein the external force calculating section includes:

a first external force calculating section for carrying
25   out a conversion to an external force of the task coordinate
system by using the disturbance torque and the minute
displacement relationship;

a second external force calculating section for carrying
out a conversion to the external force of the task coordinate
30   system by using the disturbance torque, length between the
effecting points of the external force and each axis; and

a robot axis external force average calculating section
for obtaining an average value of each of outputs of the first
external force calculating section and the second external
35   force calculating section.

6. A robot control apparatus having a position and speed system for controlling a robot and an external axis to be operated in cooperation with the robot, comprising:

a robot axis motion torque calculating section for calculating a motion torque command which is required for a motion of the robot axis based on a joint command of the robot axis;

a robot axis disturbance torque estimating section for calculating a disturbance torque from a position and speed torque command calculated by the position and speed control system and the robot axis motion torque command;

a robot axis external force calculating section for converting the robot axis disturbance torque to an external force on a task coordinate system;

an external axis motion torque calculating section for calculating a motion torque command which is required for a motion of the external axis based on a joint command of the external axis;

an external axis disturbance torque estimating section for calculating a disturbance torque from the position and speed torque command calculated by the position and speed control system and the external axis motion torque command; and

an external axis external force calculating section for converting the external axis disturbance torque to an external force on the task coordinate system.

7. The robot control apparatus according to claim 6, further comprising an external force difference calculating section for taking a difference between an external force of the robot axis to be an output of the robot axis external force calculating section and an external force of the external axis to be an output of the external axis external force calculating section, thereby obtaining an external force difference calculation value.

8. The robot control apparatus according to any of claims

1 to 7; further comprising a stop processing section for stopping at least one of each robot axis and the external axis when the external force to be the output of the external force calculating section or the external force difference calculation
5   value is greater than a preset threshold.

     9.   The robot control apparatus according to any of claims 1 to 7, further comprising an operation pendant for operating the robot,
10   the external force to be the output of the external force calculating section being displayed on the operation pendant.

     10.   A control method of a robot control apparatus having a position and speed control system for each axis of a robot
15   in order to control a servo motor for driving the axis, comprising the steps of:
         estimating a disturbance torque from a difference between a torque command calculated by modeling a robot mechanism section and a control section and a torque command output from the
20   position and speed control system;
         estimating an external force from the disturbance torque and a displacement on a task coordinate system;
         carrying out an impedance control based on the external force, thereby calculating a position correction amount; and
25   causing the position correction amount to be valid or invalid.

     11.   A control method of a robot control apparatus having a position and speed system for controlling a robot and an
30   external axis to be operated in cooperation with the robot, comprising the steps of:
         estimating a disturbance torque from a difference between a torque command calculated by modeling the robot and the external axis and a torque command output from the position and speed
35   control system;
         estimating an external force from the disturbance torque

and a displacement on a task coordinate system;

carrying out an impedance control based on the external force, thereby calculating a position correction amount; and

causing the position correction amount to be valid or
5   invalid.